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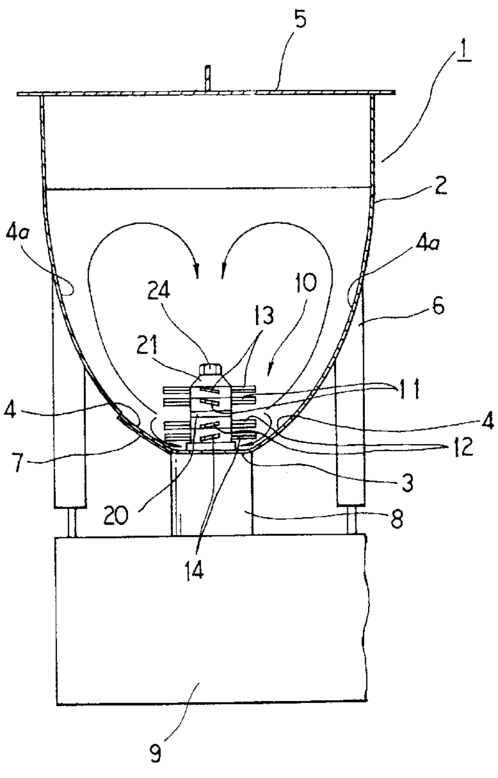
(54) **Mixing device and mixing method.**

(57) By rotating mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) having blades being inclined in opposite directions, pulverulent materials such as cement can be effectively mixed with a liquid under the most suitable condition to produce a desirable mixture. The mixing blades are opposite to each other and formed so as to have their front edges being larger in distance than their rear edges relative to the direction of rotation, thereby to cause the parts of the mixture around the respective mixing blades to come into collision with each other between the mixing blades. The mixture of high quality in which the pulverulent materials are uniformly dispersed without being left in the form of immiscible lumps with the liquid can be obtained.

FIG.1



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This invention relates to a device and method for mixing solid and liquid substances by suitable mixing action, and more particularly to a mixing device for mixing various kinds of pulverulent materials such as cement with a liquid such as water to obtain a suitable intimate mixture in which the pulverulent materials are uniformly dispersed in the mixture by rotating paired mixing blades so as to cause collisions of the particles of the pulverulent materials.

The quality of a mixture of various pulverulent materials and a liquid such as water depends on whether or not the particles of the pulverulent materials are uniformly dispersed in the resultantly obtained mixture and mixed completely with the liquid without being left in the form of immiscible lumps with the liquid. For example in the case of producing ready-mixed concrete, it was frequently difficult to produce concrete having satisfactory strength by mixing cement and aggregate with water at a time to obtain cement paste in which the cement and aggregate are consistently mixed with the water. Therefore, there is now being widely adopted a step mixing method for producing concrete, in which cement and water are first mixed to make cement paste, and thereafter, aggregate is added to and mixed with the cement paste thus made.

As typical mixers of this type, there have been so far practically used a forced stirring type pan mixer, a horizontally biaxial mixer, and a tilting mixer with a rotary drum. Every these conventional mixer is provided with a mixing blade or rotary drum as a mixing agitator means which is rotated at a low speed to break the aforenoted lumps of pulverulent particles formed in a mixture paste.

However, since such conventional mixers generally adopt a stirring mechanism utilizing gravity, aggregate mixed in the mixture paste cannot bring about an agitating action as exerted by milling balls used in a ball mill (ball mill effect) because of large absorbed energy of water in the mixture paste. Thus, the conventional mixers are restricted in ability of agitating the mixture paste. Accordingly, with the conventional mixers as noted above, theoretically, the aforementioned agitator means must be driven at high speed of rotation for a long time in order to impart kinetic energy to the aggregate in the mixture, whereas the mixture paste would be rotated sticking to the rotating agitator means or scattered away without being stirred when the agitator means is rotated at high speed. For that reason, in the conventional mixer, the mixture paste could not be agitated at high speed as a matter of course, so that the raw materials cannot be mixed sufficiently and dispersed uniformly in the mixture paste resultantly obtained.

One conventional mixing device adopting the step mixing method for making such cement paste has been proposed by Japanese Patent Publication SHO 61-7928(B). In this conventional mixing device, raw materials such as water and cement are admitted one into either end portion of a mixing drum and forcibly introduced into a pressure chamber located at the centre of the mixing drum by driving a screw to mingle the raw materials and obtain cement paste, and then, the cement paste thus obtained is fed out at a high rate of speed through a contracted path to impart a shearing force thereto.

The pulverulent particles of raw materials to be mixed tend to remain in a resultantly obtained mixture such as cement paste in the form of immiscible lumps with water, which accommodate air between the pulverulent particles in such a state that the water brings about surface tension in the mixture. Therefore, fine air bubbles in the lumps of the pulverulent materials are held in the mixture by the liquid film crosslinking effect. Though there is a case that the pulverulent particles are electrostatically joined with one another, the coherence of the pulverulent particles joined electrostatically is weaker than that by the liquid film crosslinking effect. However, in any case, the lumps of the pulverulent materials which is first brought about in the mixture cannot easily be broken merely by driving the screw used in the aforenoted conventional mixing device, because the fine air bubbles in the lumps of the pulverulent materials possibly serve as a cushion.

Furthermore, in the conventional mixing device noted above, heavy particles of the pulverulent materials in the mixture precipitates to the bottom of the mixing drum because of the difference in specific gravity of the particles. Therefore, the shearing force imparted to the cement paste occurs only at the contracted path in the mixing drum, but has no effect on the pulverulent particles precipitated to the bottom of the mixing drum.

As described above, the lumps of the pulverulent materials could not be broken effectively by the prior art including the conventional mixing device as noted above.

The inventors of the present invention have carried mainly on various studies of an energy introducing method for effectively breaking and uniformly dispersing lumps of pulverulent particles in the mixture.

From the results of their studies, it was found that the finer the pulverulent particle to be mixed with a liquid having surface tension is, the larger the cohesion thereof becomes. To be more specific, the pulverulent particles such as cement generally have a diameter of the order of about 10 μm to several ten μm, and such fine particles tend to gather and agglomerate to form a lump in a liquid. Therefore, by the conventional mixing device which intends to mechanically mix the pulverulent materials with a rotating blade or one set of blades in a mixer container, a kinetic energy sufficient to break the lumps of the pulverulent particles cannot be produced. That is to say, it is required to impart the energy directly to the lumps of the pulverulent particles in order to consistently mix the pulverulent particles with water. Further, the study made by the inventors reveals that the pulverulent particles can be dispersed uniformly in a liquid by causing collision of the particles by utilization of the difference in inertial mass between the pulverulent particles, and therefore, it is desirable to cause the pulverulent particles to collide head-on with one another.

The present invention was made on the basis of the knowledge mentioned above. Accordingly it is an object of the present invention is to provide a mixing device and mixing method capable of mixing pulverulent materials such as cement with a liquid under the most suitable condition to produce a desired mixture in which the pulverulent materials are uniformly dispersed without being left in the form of immiscible lumps with the liquid.

Another object of the present invention is to provide a mixing device and mixing method capable of effectively mixing various pulverulent materials including aggregate with a liquid to produce a suitable mixture in which the pulverulent materials are uniformly dispersed, by causing the aggregate contained in the mixture to function as milling balls generally used in a ball mill, to thereby bring about collision of the aggregate with immiscible lumps of pulverulent particles with the liquid.

To attain the object described above according to the present invention there is provided a mixing device comprising a mixing container for materials to be mixed, and at least one pair of stirring means disposed one on another vertically opposite to each other on the bottom of the mixing container at a distance.

Furthermore, the present invention provides a method for mixing pulverulent materials with a liquid to produce a mixture, comprising placing the pulverulent materials with the liquid into a mixing container, rotating, at a high speed, at least one stirring means rotatably disposed one on another vertically opposite to each other on the bottom of the container. Thus, the mixture around the respective stirring means come into collision by the high-speed rotation of said stirring means.

The stirring means may be formed of mixing blades which are vertically opposed so that the distance between the opposite front edges of the blades is larger than that between the rear edges of the same relative to the direction of rotation.

The mixing blades are rotated to produce propulsive forces in opposite directions so that the materials such as pulverulent substances and liquids around the respective mixing blades are thrust against each other to come into collision with each other between the mixing blades. The blades vertically opposite to each other of the mixing blades are so formed that the distance between their front edges is larger than that between their rear edges relative to the direction of rotation.

By rotating the mixing blades at a high speed, propulsive currents of the pulverulent materials around the respective mixing blades are brought about in the opposite directions between the opposite blades of the mixing blades, causing intense collisions of the pulverulent materials to in the region behind the rear edges of the blades. Consequently, the pulverulent materials are dispersed uniformly in a mixture obtained resultantly without being left in the form of immiscible lumps with the liquid such as water.

Fine lumps of the pulverulent materials which are possibly left in the mixture are circulated along with the mixture in the mixing container by the rotating blades and repeatedly stirred to be broken into fine particles miscible with the liquid.

The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:-

Figure 1 is a schematic diagram showing a first embodiment of the mixing device according to this invention; Figure 2 is an explanatory diagram showing the principal portion of Figure 1; Figure 3 is an exploded perspective view showing the principal portion of Figure 1; Figure 4 and Figure 5 are schematic perspective and plan views showing the principal portion in explanation of the mixing principle of this invention; Figure 6 is a schematic side view of a second embodiment of this invention; Figure 7 is an exploded perspective view showing the principal portion of Figure 6; Figure 8 is an explanatory view of a third embodiment of this invention; Figure 9 is an explanatory view of a fourth embodiment of this invention; Figure 10 is a schematic diagram showing a fifth embodiment of the mixing device according to this invention; Figure 11 is an explanatory diagram showing the principal portion of Figure 10; Figure 12 is an exploded perspective view showing the principal portion of Figure 10; Figure 13 is a schematic perspective showing the principal portion in explanation of the mixing principle of the device of Figure 10; Figure 14 is a schematic explanatory diagram showing in, part, the rotary blades as viewed from back of Figure 10; Figure 15 is a plan view of Figure 10; Figure 16 is an exploded perspective view showing the principal portion of a seventh embodiment; Figure 17 is a front view showing the principal portion of Figure 16; and Figure 18 is a perspective view showing the principal portion of an eighth embodiment of this invention.

The mixing device 1 shown in Figure 1 through Figure 3 as the first embodiment of this invention comprises a mixing container 2 for materials to be mixed, having a bottom 3 and stirring means 10. The stirring means in this embodiment are each formed of mixing blade units 12 and 13 disposed one on another vertically opposite to each other at a distance, and auxiliary mixing blades 13 and 14 are vertically disposed respectively opposite to the respective mixing blades 11 and 12 at a distance in their coaxial state.

The mixing container 2 has an inner surface 4 shaped in an arc or parabola, in section, having gradually decreasing inner diameter toward the bottom 3. That is, the inner surface 4 of the container 2 slants with slight curvature so as to permit the materials to be mixed in the container to flow from the horizontal direction to in the upward direction along the slightly curved inner surface 4. The inner surface 4 is inclined at about 25° to about 70°, preferably about 30° to about 55°. The inner surface 4 leads to a circulating guide surface 4a inclined sharply.

In the drawings, reference numeral 5 denotes a lid for covering an inlet of the container, 6 a supporting frame for the container, 7 an outlet of the container from which a mixture resultantly obtained is discharged, 8 a rotary shaft portion for the mixing blades 11-14, and 9 a basal casing accommodating an electric motor (not shown) and other elements for driving the mixing blades at a high speed.

The mixing blades 11-14 have blades 11a-11d, 12a-12d, 13a-13d, and 14a-14d which are horizontally connected crosswise to one another and each shaped in a rectangle having a narrow width. The mixing blades 11-14 are arranged in a four-layer state so as to vertically oppose the blades of one of the blades 11-14 to those of the other mixing blades as illustrated.

The opposed mixing blades 11 and 12 in the middle of the blades 11-14 are rotated in the same direction so as to cause the materials around the blades of the respective blades 11 and 12 to collide with opposite ones of the materials therebetween. For example, the blades 11a and 12a of the respective mixing blades 11 and 12 are opposed to each other so that the distance (intake side aperture) d1 between their front edges is larger than the distance (discharge side aperture) d2 between their rear edges relative to the direction of rotation indicated by the arrow R in Figure 4. That is, in a case of the blade formed of a thin plate having substantially equal thickness on the whole, the upper blade 11a is inclined downward from the front edge to the rear edge thereof relative to the direction of rotation, and the lower blade 12a is inclined upward. Namely, the upper and lower blades are inclined in the substantially opposite directions. The blades 11a-11d and 12a-12d are inclined at a degree of about 30°, preferably, in the range of about 5° to about 15 .

The upper and lower auxiliary mixing blades 13 and 14 have blades 13a-13d and 14a-14d each inclined in the same direction as that in which the blades of the adjacent mixing blade 11 or 12 disposed in the middle are inclined. Namely, the blades 13a-13d of the upper auxiliary blade 13 are each inclined downward from the front edge to the rear edge thereof relative to the direction of rotation, and the blades 14a-14d of the lower auxiliary blade 14 are each inclined upward from the front edge to the rear edge. The blades 13a-13d and 14a-14d are inclined at a degree of about 30°, preferably, in the range of about 5° to about 15°, in the same manner as the middle mixing blades 11 and 12.

To be more specific, the mixing blades 11-14 each may be formed by radially extending the blades from a hub 16 fitted to a rotary shaft 17, as one example. In this case, each mixing blade may be engaged with the rotary shaft 17 by means of a key groove 18 and a key 19. Between the hubs 16 of the mixing blades 11 and 12, there may be interposed a gap adjusting member 20 shaped in a ring having the same diameter as the hub 16. A plurality of gap adjusting members different in height may be prepared so that the distance between the mixing blades 11 and 12 can be selectively changed in accordance with the specific gravity and viscosity of the mixture to be dealt with by this mixing device, the rotational speed of the mixing blades and other possible factors. By adjusting the height (h) of the gap adjusting member 20, the mixture in the container can properly flow and be sufficiently mixed. Thus, the mixture parts around the blades 11a and 12a are effectively propelled by the rotating blades and collide with each other in the region A1 and A2 behind the blades relative to the direction of rotation.

The mixing blades 11-14 and the gap adjusting member 20 are fixed onto the rotary shaft 17 by screwing as shown in Figure 3. That is, the rotary shaft 17 is formed with a screw hole 22, and a fixing member 21 having a screw 23 and a nut 24 is used. By tightening up the screw 23 in the screw hole 22, the mixing blades and gap adjusting member can be fixed.

Next, the operation of mixing pulverulent materials with a liquid by using the aforenoted mixing device according to this invention will be explained hereinafter.

Upon pouring the liquid such as water into the mixing container 2, the mixing blades 11-14 are driven to rotate the blades 11a-11d, 12a-12d, 13a-13d and 14a-14d at a high speed so as to bring about a strong current of water. By the rotating blades 11a-11d and 12a-12d, the upward and downward currents (f1) of water occur, and then, collide with each other at the regions A1 and A2. Since the intake side distance d1 is larger than the discharge side distance d2, the water flowing into between the blades 11a and 12a through the intake side aperture d1 is accelerated to be discharged backward through the discharge side aperture d2 at a high speed.

Next, pulverulent materials such as cement and aggregate are added to the water in the mixing container 2. Since the fine particles of the pulverulent materials, if agglomerating densely, are immiscible with water, the pulverulent materials tend to remain in the form of numerous lumps in a resultantly obtained mixture containing the water. However, the mixture including the lumps of the pulverulent materials are sufficiently stirred by the rotating blades. Moreover, by rotating the mixing blades at a high speed, the the parts of the mixture around the upper and lower mixing blades 11 and 12 are thrust downward and upward and collide intensely with each other at the regions A1 and A2 to break the lumps of the pulverulent materials into fine particles miscible with water. The fine particles of the pulverulent materials are consequently dispersed uniformly in the mixture.

To be more exact, the collisions of the lumps of the pulverulent materials are first caused in the region A1 behind the rotating blades 11a-11d and 12a-12d and further developed to the region A2 as shown in Figures 4 and 5. Thus, the lumps of the pulverulent materials would be completely broken.

The pulverulent materials reach the region A4 separated from the inner wall surface 4 of the container 2 while being dispersed in the mixture and split in two upward and downward along the inner wall surface 4 to be circulated by convection.

Simultaneously the parts of the mixture around the blades 13a-13d and 14a-14d of the upper and lower auxiliary mixing blades 13 and 14 are propelled by the rotating blades 13a-13d and 14a-14d toward the region A2 or A4 via the region A3 to form currents f2. The currents f2 of the mixture also contribute toward breaking the lumps of the pulverulent materials in the mixture.

The mixing blades are rotated at such a rate that the outer edge of the rotating blade makes a circumferential speed of about 2 meters per minute to about 70 meters per minute, preferably about 8 meters per minute to about 55 meters per minute. In this range of the circumferential speed, sufficient difference in inertial mass between the pulverulent particles contained in the mixture can be acquired.

To confirm the performance of the mixing device of this invention, experiments were conducted through a flow point test and a bleeding test. In the experiments, mixture paste obtained by the mixing device of this invention was compared with that by a conventional forced pan-type mixing device. It is evident from the results of the experiments shown in TABLE 1 below that high flow property of the mixture paste in the mixing container can be provided resulting in production of the mixture of high quality according to the present invention.

TABLE 1

(Comparison on mixture paste)

[Conditions] Water-cement ratio = 40%
Ordinary Portland cement only used.

Mixer	Flow-down Time in Funnel	Bleeding Amount
Present Invention	14.2 sec	1.4%
Conventional Mixer	17.2-20.0 sec	2.0%

Further, the superiority of the mixing device according to this invention in comparison with the conventional forced pan-type mixing device could be proved experimentally as is obvious from TABLE 2 below.

TABLE 2

		Mixer of Present Invention			Conventional Forced Pan Mixer		
Water-Cement Ratio %		30	35	40	30	35	40
Aggregate-Cement Ratio %		41.8	44.1	45.7	41.8	44.1	45.7
Unit Weight (kg/m)	Water	170	170	170	170	170	170
	Cement	567	486	425	567	486	425
	Fine Aggregate	694	760	813	694	760	813
	Coarse Aggregate (*1)	969	969	969	969	969	969
RHEOBUILD SP-9HS (CX%)		1.3	0.9	1.0	1.7	1.5	1.4
Slump & Flow (cm)		21.5 35x35	20.0 31x31	20.0 33x32	18.0 30x28	18.0 28x28	20.0 33x32
Slump after 20min. (cm) (*2)		23.0 39x38	16.5 28x26	20.0 33x28	19.5 30x28	18.0 29x28	19.0 28x28

[Conditions] Mixing time was constant.
Compressive strength was kept equal.
*1...Bulk capacity of coarse aggregate was 0.60 m/m .
*2...Slump obtained 20 minutes after completion of mixing was measured with mixed concrete maintained at rest.

Next, the second embodiment of the mixing device according to this invention will be described with reference to Figure 6 and Figure 7.

This mixing device has a spiral blade 30 for promoting circulation of the mixture in the container 2 and mixing blades 11, 12, 13 and 14 similarly to the foregoing embodiment. The spiral blade 30 is formed on the circumferential surface of a fixing member 31 for fixing the mixing blades 11-14 onto the rotary shaft 17. In this embodiment, the elements indicated by like reference numerals with respect to those of the first embodiment have analogous structures and functions to those of the first embodiment and will not be described in detail again.

This mixing device having the spiral blade 30 enables even pulverulent materials having high viscosity such as cement mortar to be effectively circulated and mixed in the container.

Figure 8 illustrates the third embodiment having a modified blade structure. In this embodiment, there are used opposite blades 40, 41 which are curved inwardly like a bird bill when viewed from the side.

The curved blades 40, 41 are effective particularly for pulverulent materials of fine or light particles. To the curved blades 40, 41 there may be exerted vibration to promote mixing of the pulverulent materials in the container.

As shown in Figure 9 as the fourth embodiment of this invention, each mixing blade 42 is provided with an expansion portion 43 extending backward from the rear edge of the blade relative to the direction of rotation. This mixing blade 42 can possibly produce a more strong current of pulverulent materials in the container. One mixing blade has the plural blades 42 as indicated by the chain line in Figure 9. The number of the blades 42 may be arbitrarily decided, e.g. three, four, five or more.

The fifth embodiment of the invention is illustrated in Figure 10 through Figure 16. In this and subsequent embodiments, the reference numerals which have equivalents in the drawings of the embodiment mentioned above denote identical or equal component parts. The description of these component parts is omitted below to avoid repetition.

The stirring means 51 in this embodiment is formed of screw blades 51 and 52 are each fixed on a hub 55 or 56 so as to be inclined spirally round the corresponding hub. Each screw blade 51, 52 assumes a sector shape as viewed from above having the central angle of about 30° to about 270°. The central angle of the screw blade may be determined in accordance with the viscosity and specific gravity of the mixing materials to be dealt with. When the central angle is less than 30°, sufficient propulsive force would not be obtained. When the central angle is larger than 270°, it becomes difficult to introduce the mixing materials into between the screw blades. In a case of dealing with mortar, it is preferable to determine the central angle of the screw blade to about 60° to about 120°.

The screw blades 51 and 52 may be used in pairs so that each pair of the blades are opposite to each other with a hub 55 or 56 between them. The paired screw blades 51, 52 are vertically superposed one on another with and rotated to cause collision of propulsive currents of the mixture in the space between the rotating blades. Each pair of the opposed blades have front edges separated widely relative to the direction of rotation to form a wide intake aperture d1 and rear edges separated narrowly to form a narrow discharge aperture d2. As a result, by rotating the screw blades 51, 52 in the mixture in the same direction, a high pressure current α of the mixture is discharged from the discharge aperture d2 formed between the screw blades.

In a case of the blade formed of a thin plate having substantially equal in thickness on the whole, the upper screw blade 51 is spirally inclined downward from the front edge to the rear edge thereof relative to the direction of rotation, oppositely, the lower screw blade 52 is spirally inclined upward. Namely, the upper and lower screw blades are inclined in the substantially opposite directions as opposed to each other in action. The angle at which the screw blades 51 and 52 are inclined may be at least about 3° at which the current of the mixture can be changed in direction. The screw blades may be inclined at about 40° or less so as not to intercept the flowing of the mixture between the screw blades. The inclination of the screw blade may preferably be determined in the range of about 5° to about 15° in the case of mixing mortar.

The screw blades 51, 52 may be inclined in the radial direction so that the space between the opposite screw blades becomes narrower from their inner circumferential ends connected to the hubs 55, 56 toward the outer circumferential edges thereof so as to prevent the mixture flowing between the screw blades from escaping sideward. It is desirable to form opposite protrusions 54 on the outer circumferential edge portion as shown in Figure 14 in order to heighten the effect of preventing the sideward escaping of the mixture between the screw blades.

To be more concrete, the screw blades 51, 52 (51A, 51B, 52A, 52B) each extend radially outward from the hub 55 or 56 fitted to a rotary shaft 57. In this case, each screw blade may be engaged with the rotary shaft 57 by means of a key groove 58 and a key 59. Between the hubs 55, 56 of the screw blades 51 and 52, there may be interposed a gap adjusting member 20 shaped in a ring having the same diameter as the hubs 55 and 56. A plurality of gap adjusting members different in height (h) may be prepared so that the distance between the screw blades 51 and 52 can be selectively changed in accordance with the specific gravity and viscosity of the mixture to be dealt with by this mixing device, the rotational speed of the screw blades and other possible factors. By adjusting the height (h) of the gap adjusting member 20, the mixture in the container can properly flow and be sufficiently mixed. Thus, the mixture parts around the screw blades 51 and 52 are effectively propelled by the rotating blades and collide with each other in the region behind the blades relative to the direction of rotation.

This mixing device may be provided with a circulating blade 30 for promoting circulation of the mixture in the container in consideration with viscosity of the mixture to be dealt with. The circulating blade 30 is equivalent to that in the second embodiment shown in Figure 15.

Next, a method of mixing cement with water, for example, by use of the mixing device of the fifth embodiment described above will be explained hereinafter.

Upon pouring a liquid such as water into the mixing container 2, the screw blades 51, 52 are rotated at high speed so as to bring about a strong current of water. By the rotating screw blades 51, 52, the upward and downward propulsive currents of water occur between the blades 51A and 52A and between the blades 51B and 52B. The currents of water occurring around the blades 51A and 51B are directed downward at an angle according to the inclination of the screw blades 51A and 51B, and those around the blades 52A and 52B are directed upward at an angle according to the inclination of the screw blades 52A and 52B. Since the intake aperture d1 between the front edges of the blades 51 and 52 are wider than the discharge aperture d2 between the rear edges of the same, the water flowing between the blades is discharged therefrom with increasing speed.

Next, pulverulent materials such as AE agents and cement are added to the water in the mixing container 2. At this time, as a matter of course, the pulverulent materials tend to gather in the water to form lumps of pulverulent particles (Q) which become immiscible with water.

Thereafter, fine aggregate (S) such as sand is added. With the rotation of the screw blades, difference in inertia between the lumps of pulverulent particles (Q) and the fine aggregate particles is brought about. Although the aggregate particle is as small as about 0.1 mm to about 2 mm in diameter, it is caused to collide with the lumps of pulverulent particles by the rotating screw blades 51, 52, thereby to break the lumps of pulverulent particles (Q). Such collision of the aggregate particles with the lumps of pulverulent particles occurs not only in the region between the blades but also at the regions around and behind the screw blades relative to the direction of rotation, involving the so-called ball mill effect brought about by the aggregate particles agitated by the rotating screw blades with heavy pressure. The high pressure produced between the rotating screw blades can be determined to a desired value by adjusting the height (h) of the gap adjusting member 20.

Since the space between the screw blades are narrower toward the discharge aperture d2, the current of the mixture flowing between the blades becomes gradually fast with advancing toward discharge aperture d2. The ball mill effect brought about by the aggregate particles contained in the mixture is simultaneously enhanced to strongly break and disperse the lumps of pulverulent particles in the mixture, as illustrated in Figure 13.

The pulverulent particles thus dispersed in the mixture in the space between the screw blades are discharged with increasing speed from the discharge aperture d2 as if it passes through an orifice, and then, horizontally move straight backward as indicated by the imaginary arrows in Figure 15. As a result, the fine aggregate particles having high inertia rush into the lumps of pulverulent particles (Q) staying statically at the region around the inner wall surface 4 of the mixing container 2, which is indicated by two-dot chain lines in the drawing. Thus, the lumps of pulverulent particles in the mixture are effectively broken by the aggregate particles serving as an agitator like milling balls in a ball mill and dispersed uniformly in the mixture.

The pulverulent particles thus dispersed go away from the discharge aperture d2 with the mixture and advance upward and downward along the inner wall surface 4 of the container without sticking to the wall surface of the container. Then, the mixture is circulated by convection caused by rotating the screw blades in the mixing container. Since the container 2 has a substantially parabolic configuration, the mixture which is discharged horizontally backward from the discharge aperture d2 mostly advances upward along the inner wall surface 4 of the container. The mixture moved upward is again introduced into between the screw blades by the rotating blades 51, 52 and the circulating blades 30. This circulation of the mixture is repeated.

The sixth embodiment of the mixing device of this invention is shown in Figure 16 and Figure 17. This mixing device is provided with screw blades 61 and 62 which define a space therebetween having a height equal in section in the horizontal direction, but has no circulating blade. Also in this embodiment, high speed collision of the mixture occurs around the rear edge portions of the screw blades to make a current of the mixture of high pressure, and lumps of pulverulent particles which are inevitably formed by initially mixing the pulverulent particles with water are effectively broken and uniformly dispersed in the form of fine particles in the mixture by the ball mill effect of the aggregate particles contained in the mixture which are agitated by the rotating screw blades 61, 62 at high speed. The mixing device of this embodiment is fit particularly for mixing pulverulent materials having low viscosity.

Figure 18 shows the seventh embodiment of this invention. The mixing device of this embodiment has screw blades 71 and 72 which are curved in the radial direction in such a state that their outer circumferential edges are close to each other. The front edge of each screw blade has the width (r) smaller than the width (r+n) of the rear edge thereof. With this embodiment, the pulverulent particles can be more uniformly dispersed in the mixture by rotating the screw blades.

Though the foregoing explanation is made as to the mixing device applied particularly to cement paste, the present invention can be adapted for mixing various pulverulent materials regardless of the size of the particle and the viscosity of the mixture by arbitrarily determining the rotational speed and shape of the blades and the shape of the container in compliance with numerous uses. The mixing device of the present invention can be applied practically in its modified form to various fields of foods, medicines, metals, ceramics, plastics, livestock feed and so on.

As is apparent from the foregoing, according to the mixing device and method of the present invention, various sorts of pulverulent materials such as cement can be effectively mixed with a liquid under the most suitable condition to produce a desirable mixture in which the pulverulent materials are uniformly dispersed without being left in the form of immiscible lumps with the liquid which are inevitably formed in the mixture of the pulverulent materials.

Furthermore, since the aggregate contained in the mixture brings about the ball mill effect by rotating the screw blades so as to collision of the aggregate particles with immiscible lumps of the pulverulent materials with water inevitably formed in the mixture. Therefore, the mixture of high quality in which the pulverulent materials are uniformly dispersed can be obtained.

Claims

1. A mixing device comprising a mixing container (2) for materials to be mixed, and a stirring means (10) for mixing materials, characterised in that said stirring means is composed of at least one pair of mixing blades

(11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) extending radially outward and being rotatably disposed vertically opposite to each other on the bottom (3) of the mixing container (2) at a distance, so as to have their front edges being larger in distance than their rear edges relative to the direction of rotation, thereby to cause the materials around the respective mixing blades in said container to come into collision with each other.

2. A mixing device according to claim 1 wherein said mixing blades (11, 12, 40, 41, 42) are each formed of a thin plate having substantially equal thickness, said upper blade being inclined downward from the front edge to the rear edge thereof relative to the direction of rotation, and the lower blade being inclined upward.

3. A mixing device according to claim 1 or claim 2 further comprising auxiliary mixing blades (12, 13) vertically disposed coaxially opposite to said mixing blades (11, 12, 40, 41, 42) at a distance, respectively.

4. A mixing device according to claim 1 wherein said mixing blades (51, 52, 61, 62, 71, 72) are each formed in a spiral shape and disposed one on another vertically opposite to each other on the bottom (3) of said mixing container (2), said screw blades being rotated at high speed to cause the mixing materials to fast flow between the screw blades and serve the aggregate contained in the mixing materials as a mixing agitator.

5. A mixing device according to any of claims 1 to 4 further comprising a gap adjusting member (20) interposed between said mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72).

6. A mixing device according to and of claims 1 to 5 wherein said mixing container (2) has an inner wall surface shaped in an arc or parabola, in section, having gradually decreasing inner diameter toward the bottom (3) of said container, which inner wall surface (4) slants with slight curvature so as to permit the materials in said container to flow from the horizontal direction to the upward direction along said inner wall surface.

7. A mixing device according to and of claims 1 to 6 further comprising a spiral blade (30) for circulating the mixture in said container (2), said spiral blade being disposed on said mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72).

8. A mixing device according to any preceding claim wherein said mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) having outer edges are rotated at such a speed that the outer edge of the rotating blade makes a circumferential speed of about 2 meters per minute to about 70 meters per minute.

9. A mixing device according to any preceding claim wherein said mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) having outer edges are rotated at such a speed that the outer edge of the rotating blade makes a circumferential speed of about 8 meters per minute to about 55 meters per minute.

10. A mixing device according to any preceding claim wherein said mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) each assume a sector shape as viewed from above, having a central angle of about 30° to about 270°.

11. A mixing device according to any preceding claim wherein said mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) each assume a sector shape as viewed from above, having a central angle of about 60° to about 120°.

12. A method for mixing pulverulent materials with a liquid to produce a mixture, comprising placing the pulverulent materials with the liquid into a mixing container (2), rotating, at a high speed, mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) radially extending outward, which mixing blades are rotatably disposed vertically opposite to each other on the bottom (3) of said container (2), whereby said mixture around the respective mixing blades come into collision by the high-speed rotation of said mixing blades.

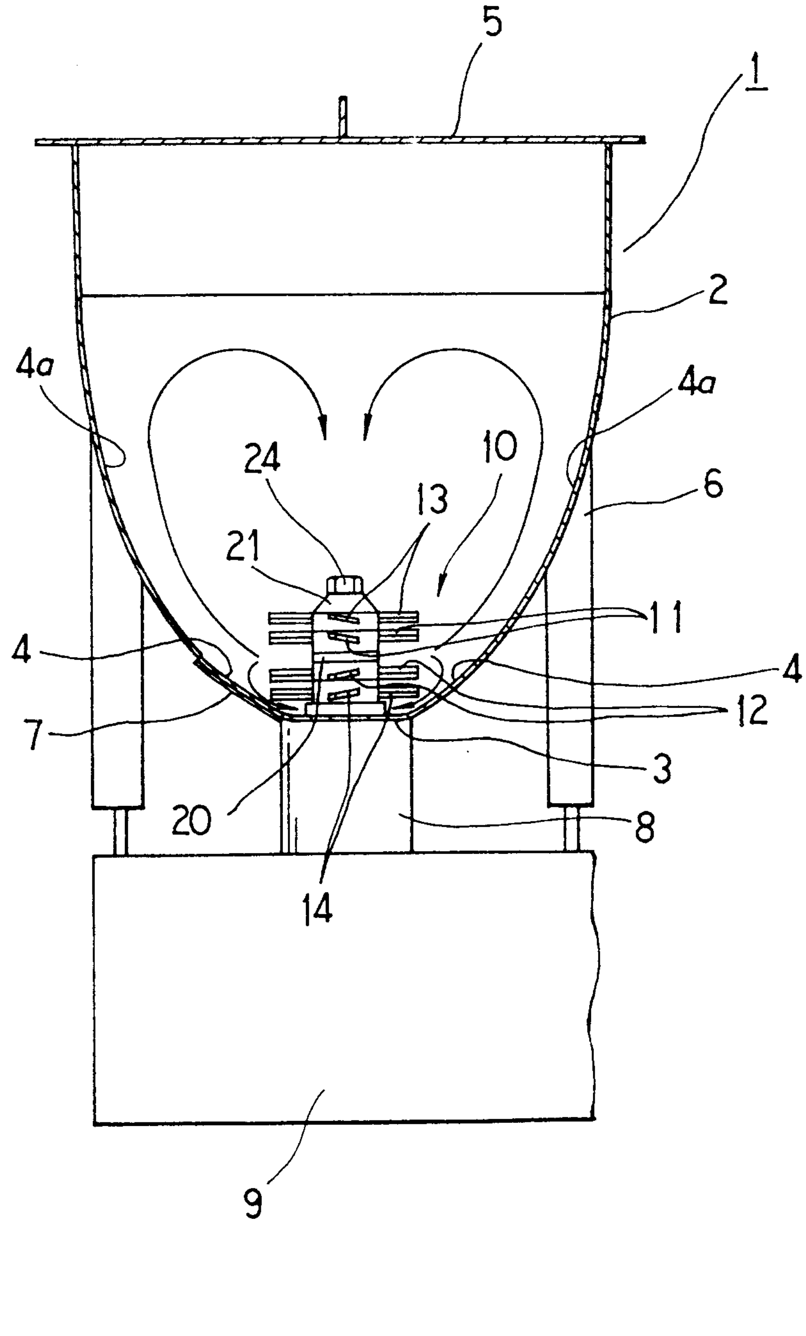
13. A mixing method according to claim 12 wherein said mixing blades (11, 12, 40, 41, 42, 51, 52, 61, 62, 71, 72) are rotated at such a speed that the outer edge of the rotating blade makes a circumferential speed of about 2 meters per minute to about 70 meters per minute.

14. A mixing method according to claim 12 or 13 wherein said mixing blades (11, 12, 40, 41, 42, 51, 52, 61,

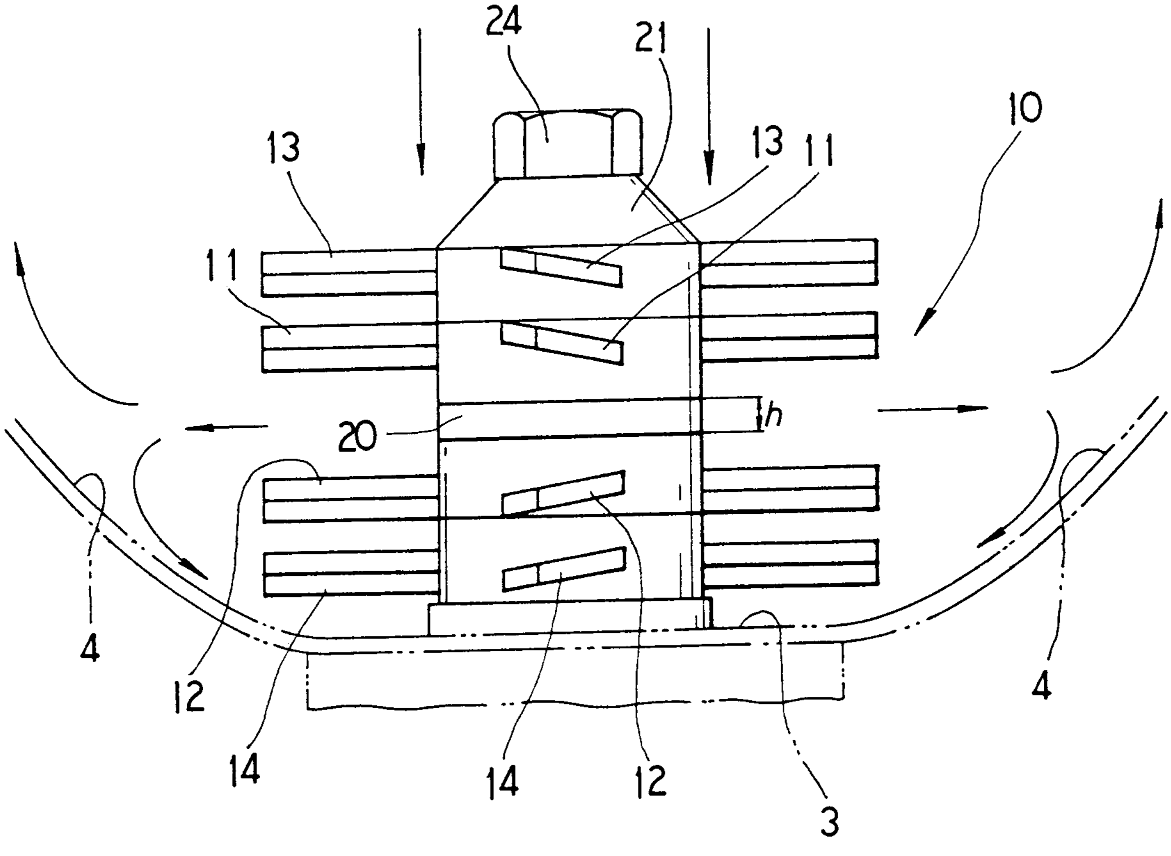
62, 71, 72) are rotated at such a speed that the outer edge of the rotating blade makes a circumferential speed of about 8 meters per minute to about 55 meters per minute.

15. A mixing method according to any of claims 12 to 14 wherein said pulverulent materials are dispersed in the mixture in a region (A4) separated from the inner wall surface (4) of said container (2) and split in two upward and downward along said inner wall surface to be circulated by convection.

FIG.1



F I G. 2



F I G. 3

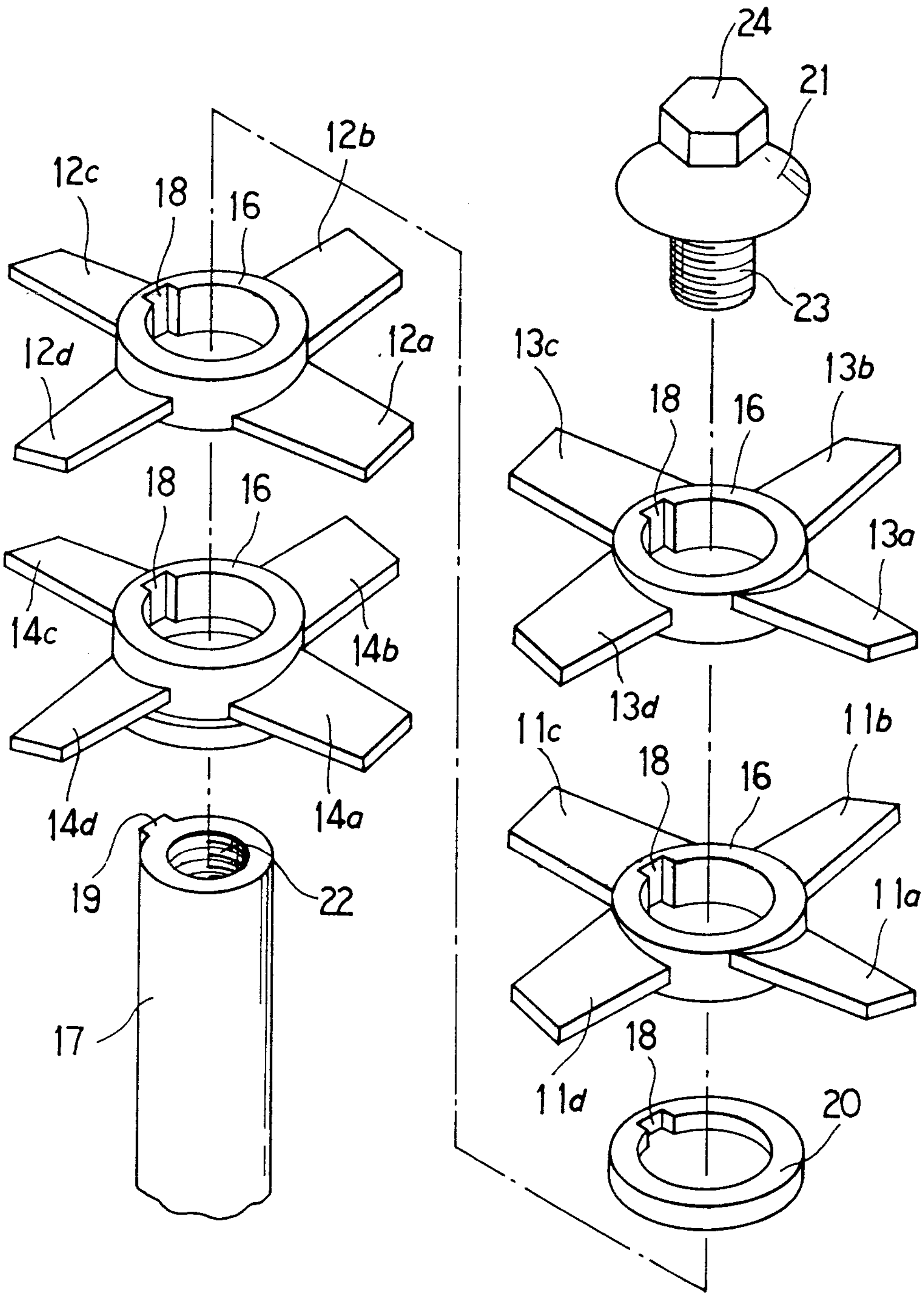

24
21
23
12b
12c
18
16
12a
12d
13c
13b
18
16
18
16
13a
14c
14b
13d
14d
14a
11c
11b
18
16
19
22
11a
17
18
11d
20

FIG.4

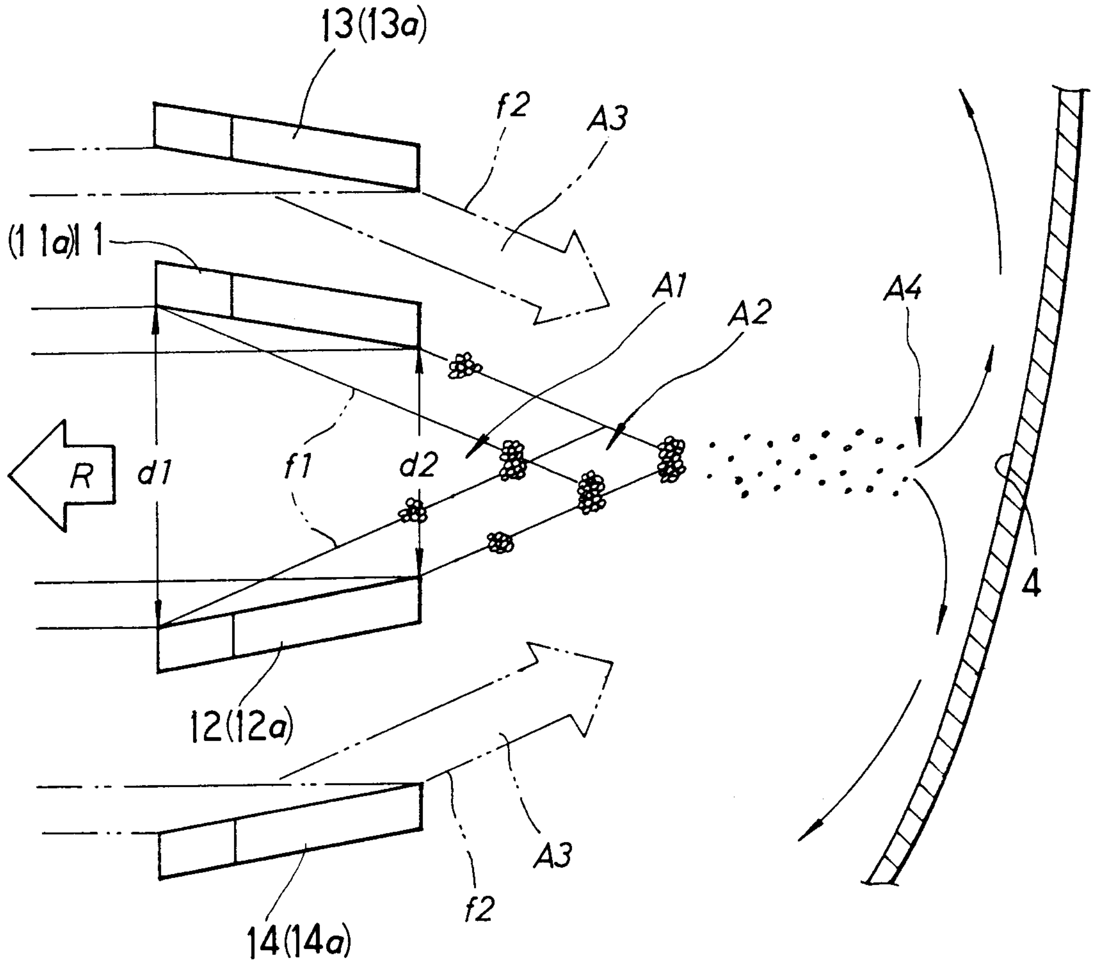


FIG. 5

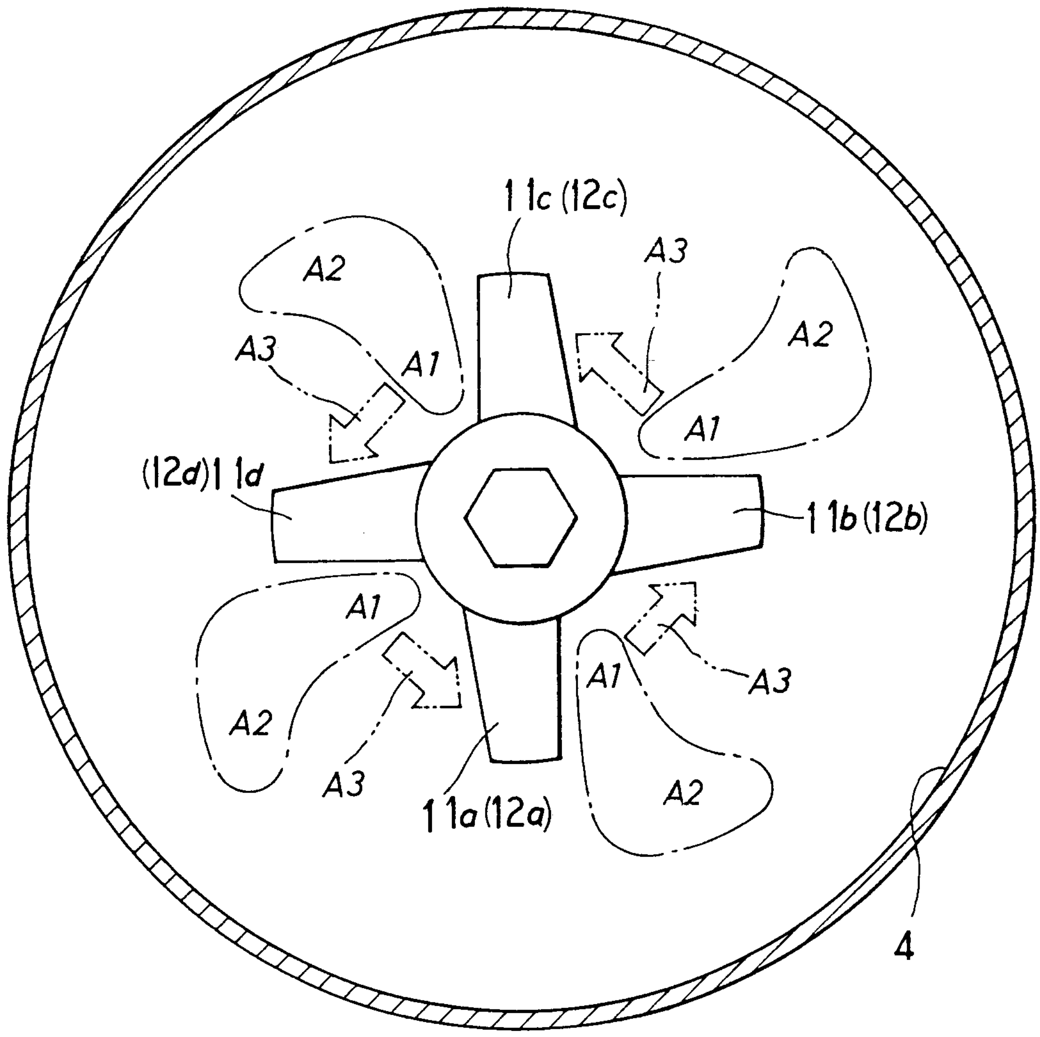

11c (12c)
A2
A3
A2
A3
A1
A1
(12d) 11d
11b (12b)
A1
A1
A3
A2
A1
A3
A2
A3
11a (12a)
4

FIG. 6

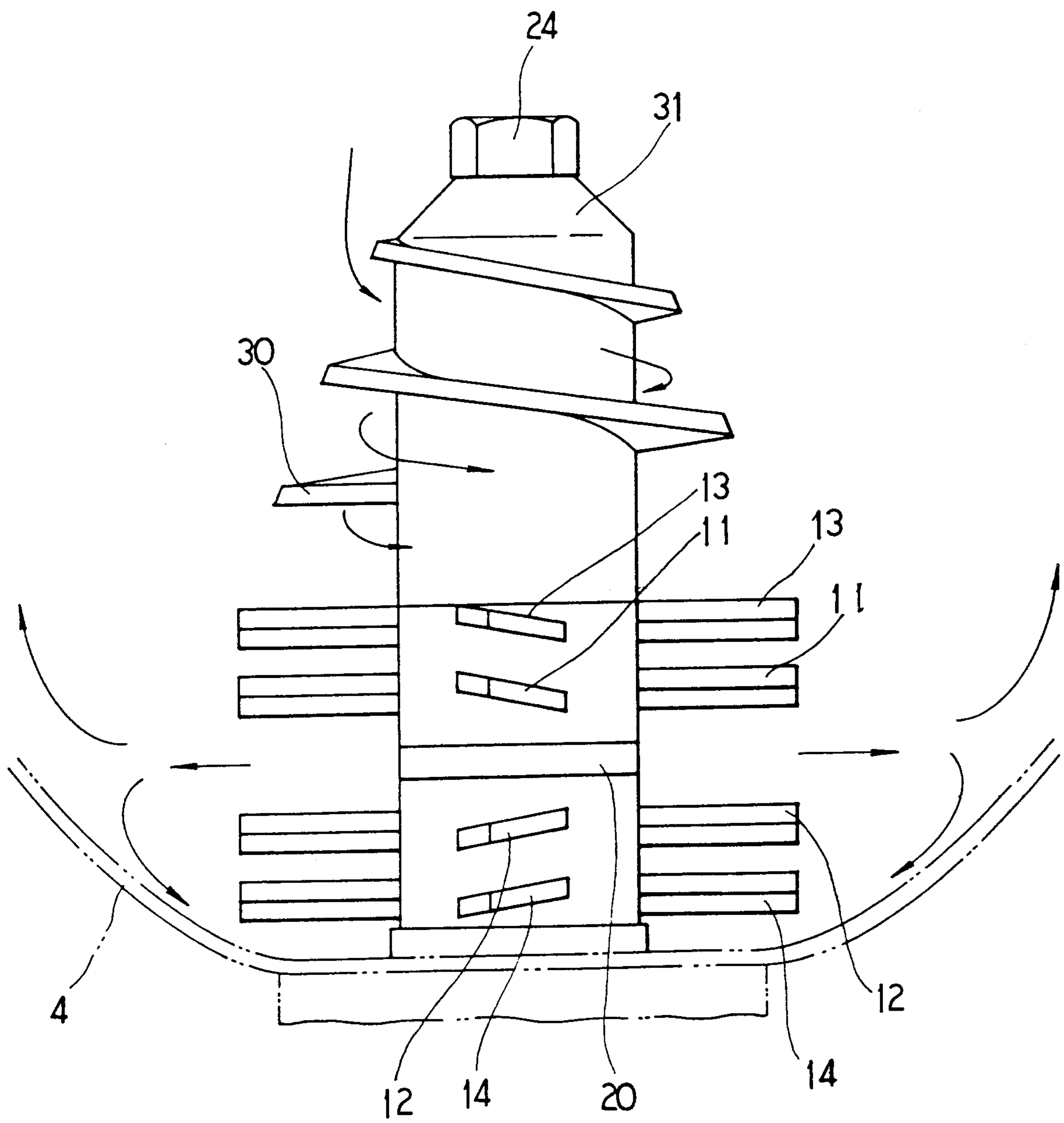


FIG. 7

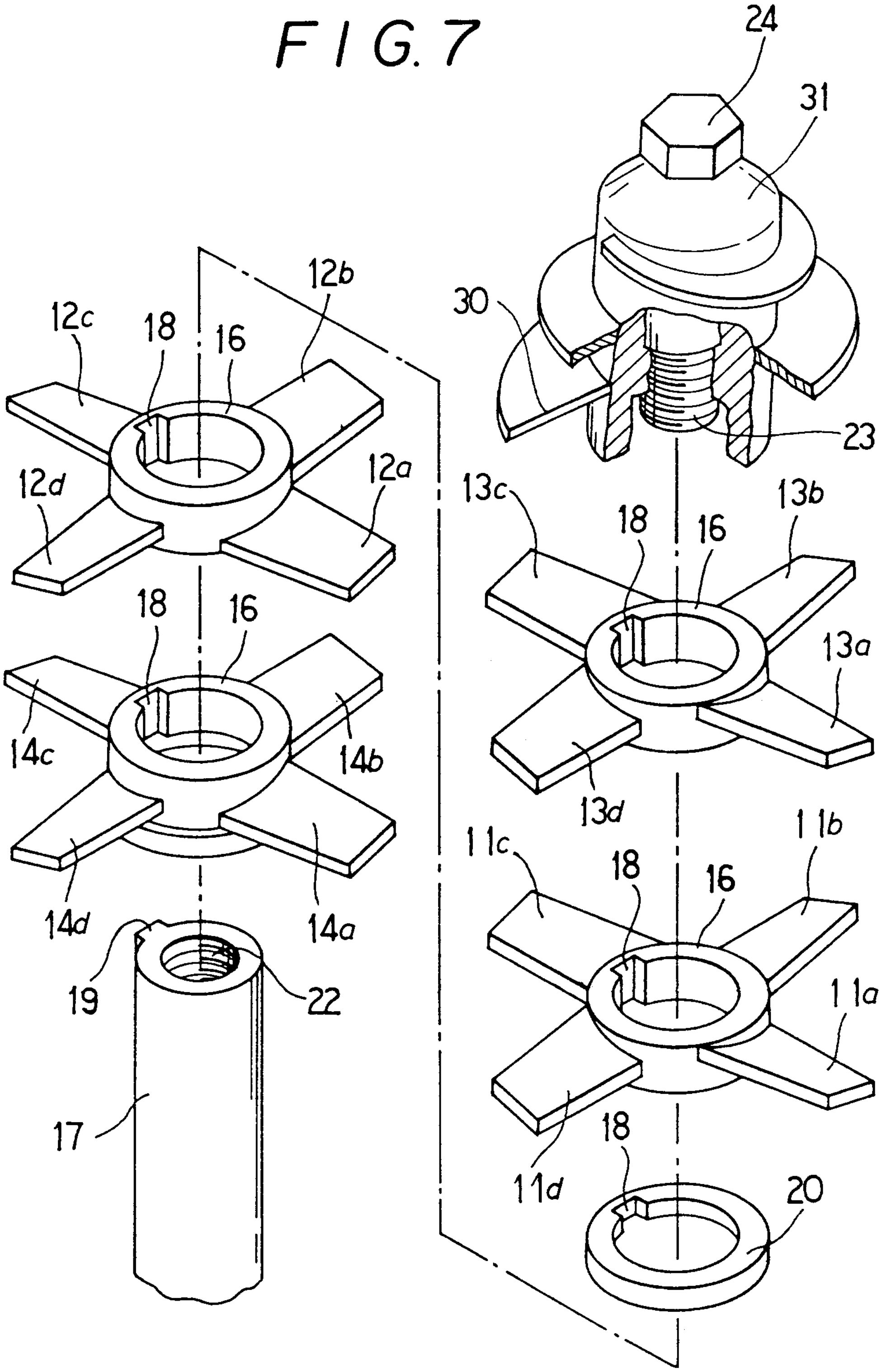

24
31
30
23
12b
12c
18
16
12d
12a
13c
18
16
13b
13a
13d
18
16
14c
14b
14d
14a
19
22
17
11c
18
16
11b
11a
11d
18
20

FIG. 8

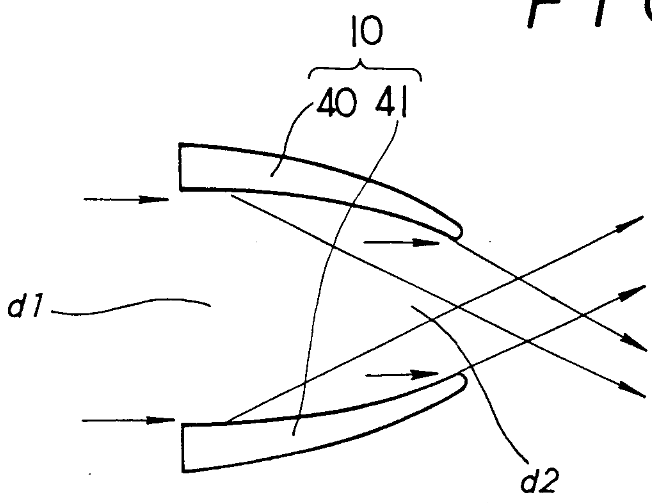


FIG. 9

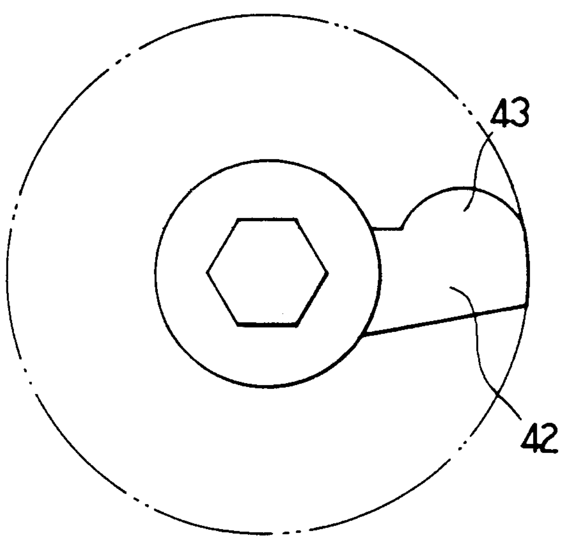


FIG.10

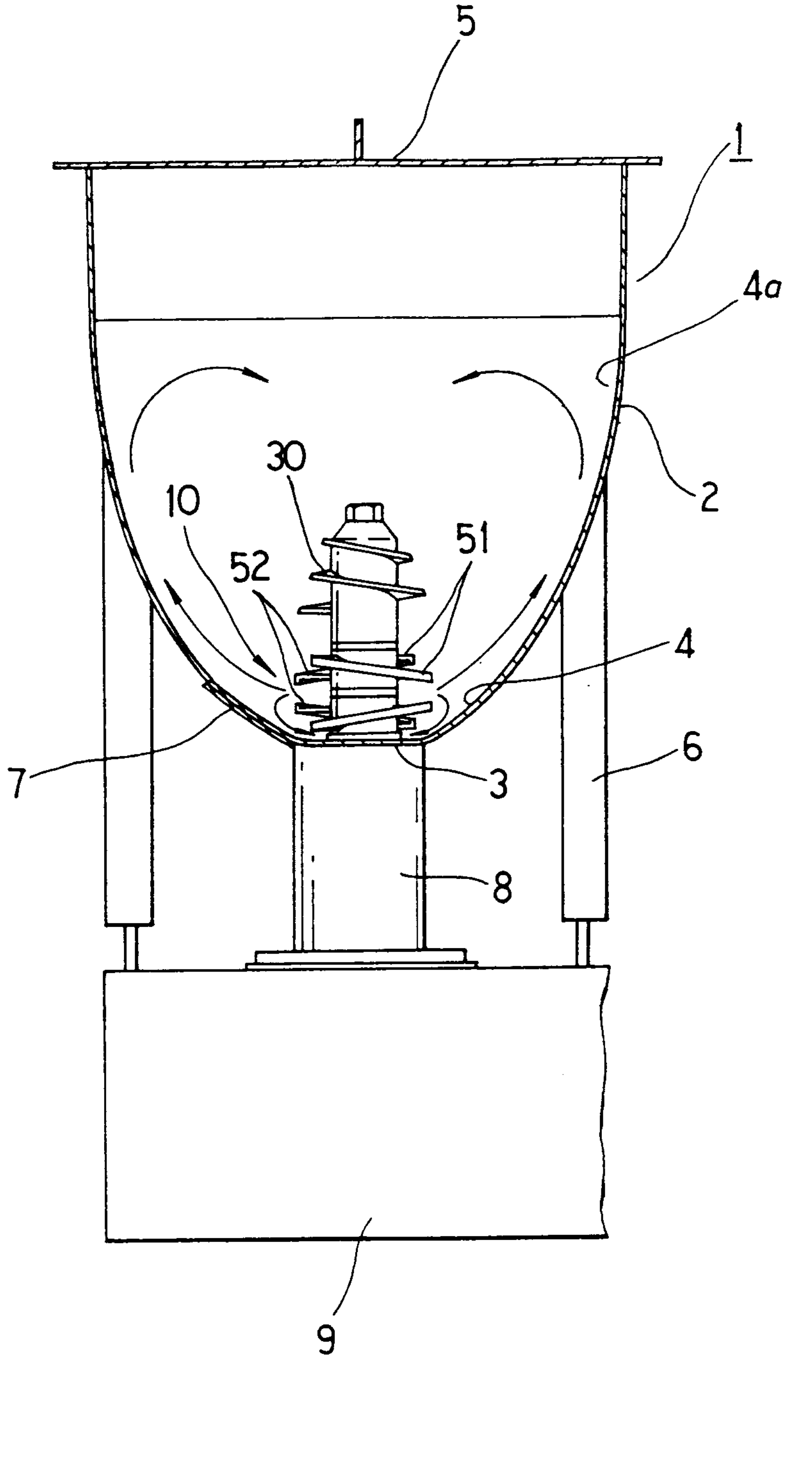
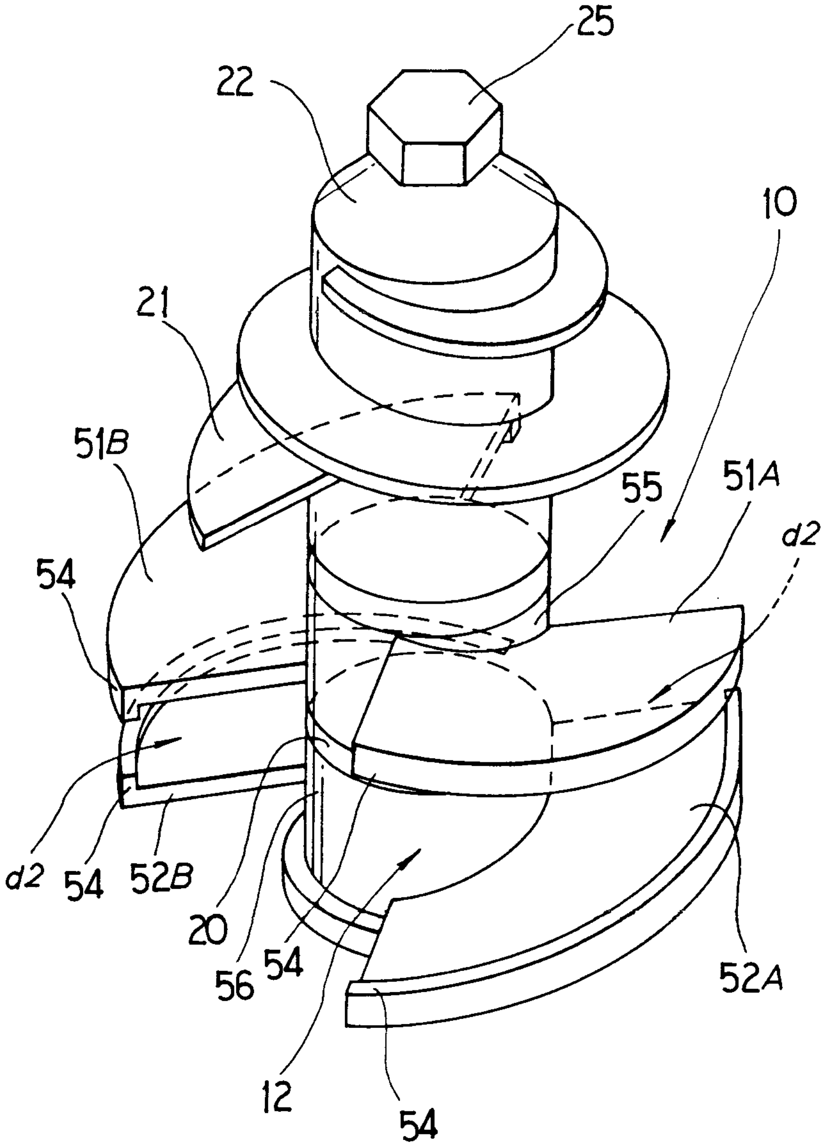


FIG.11



F I G.12

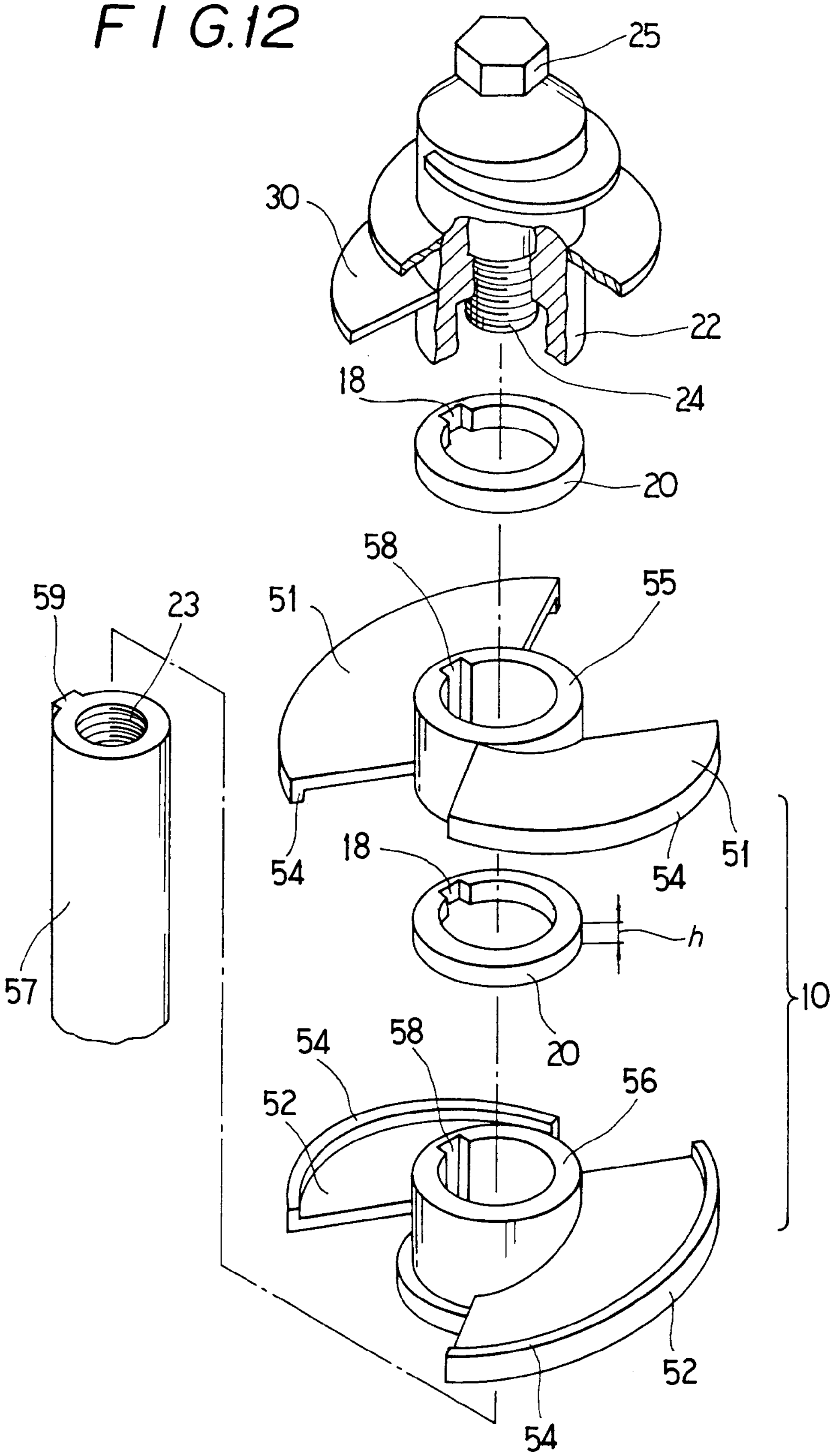


FIG.13

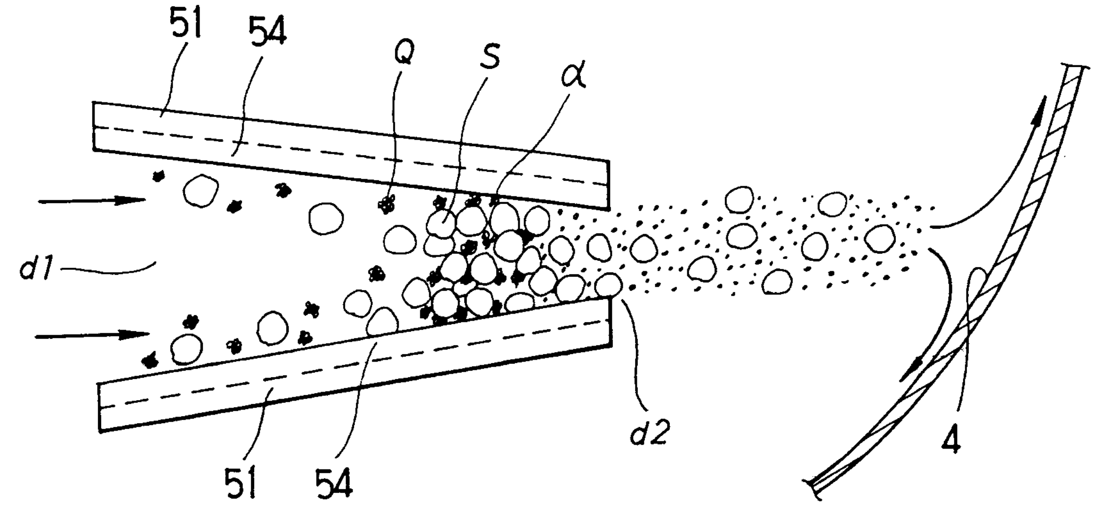


FIG.14

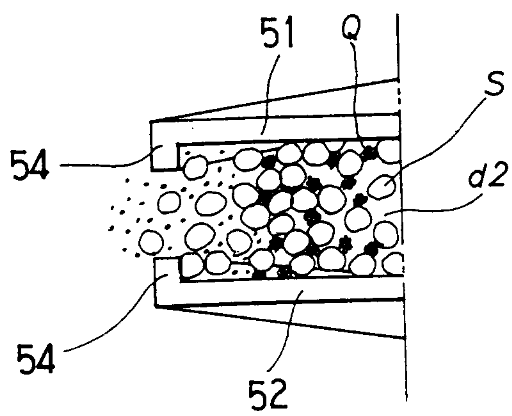


FIG.15

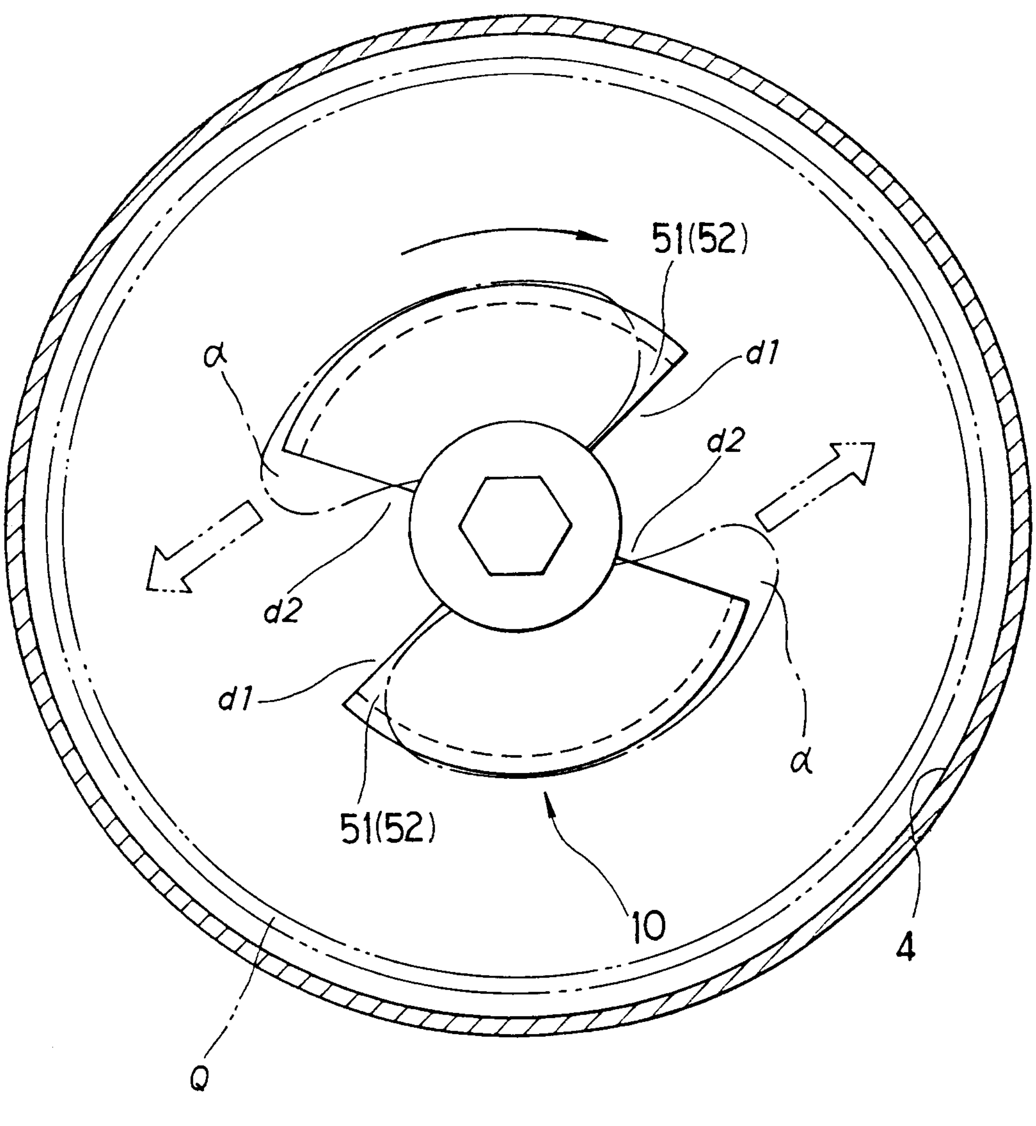


FIG.16

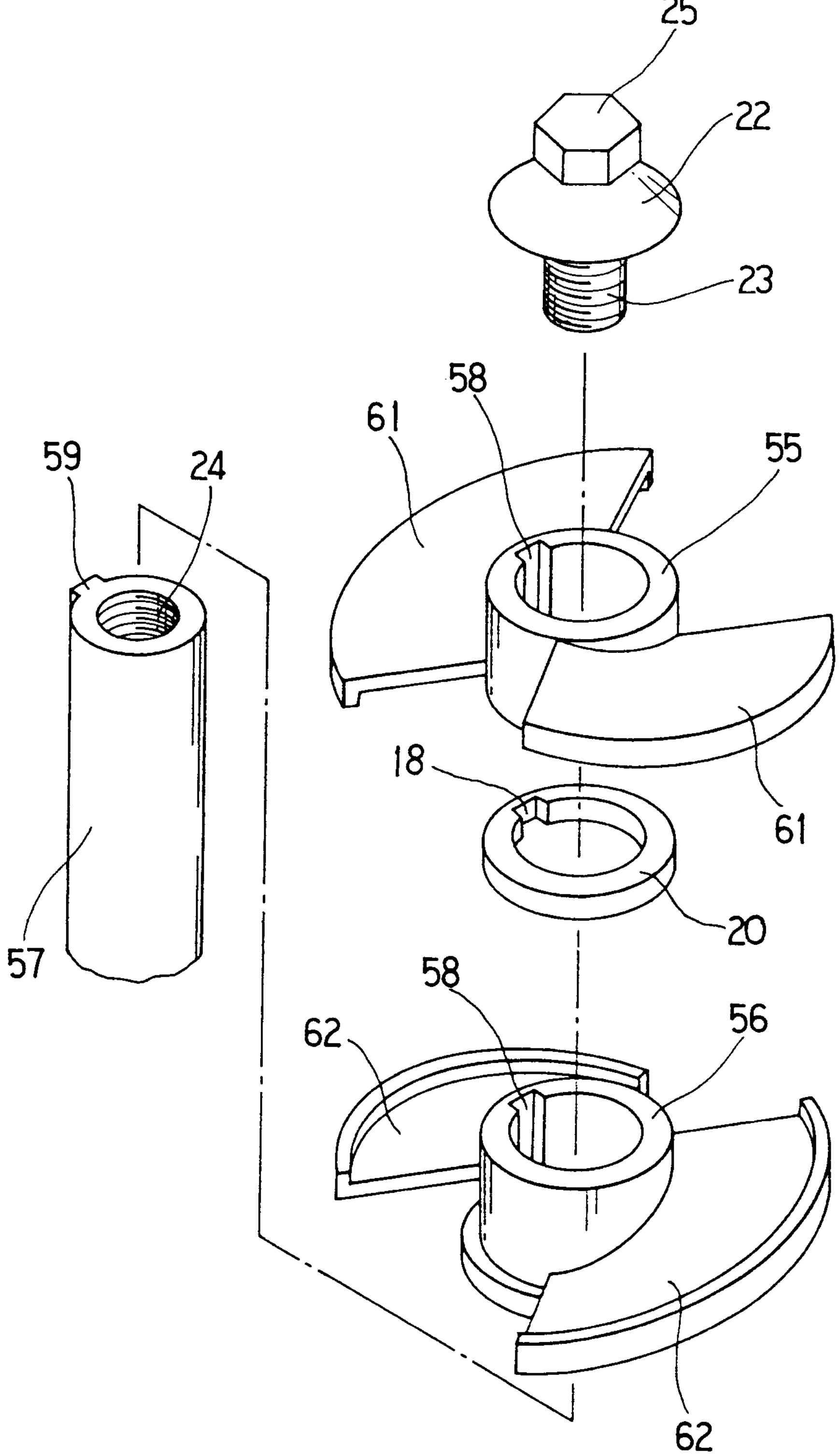


FIG.17

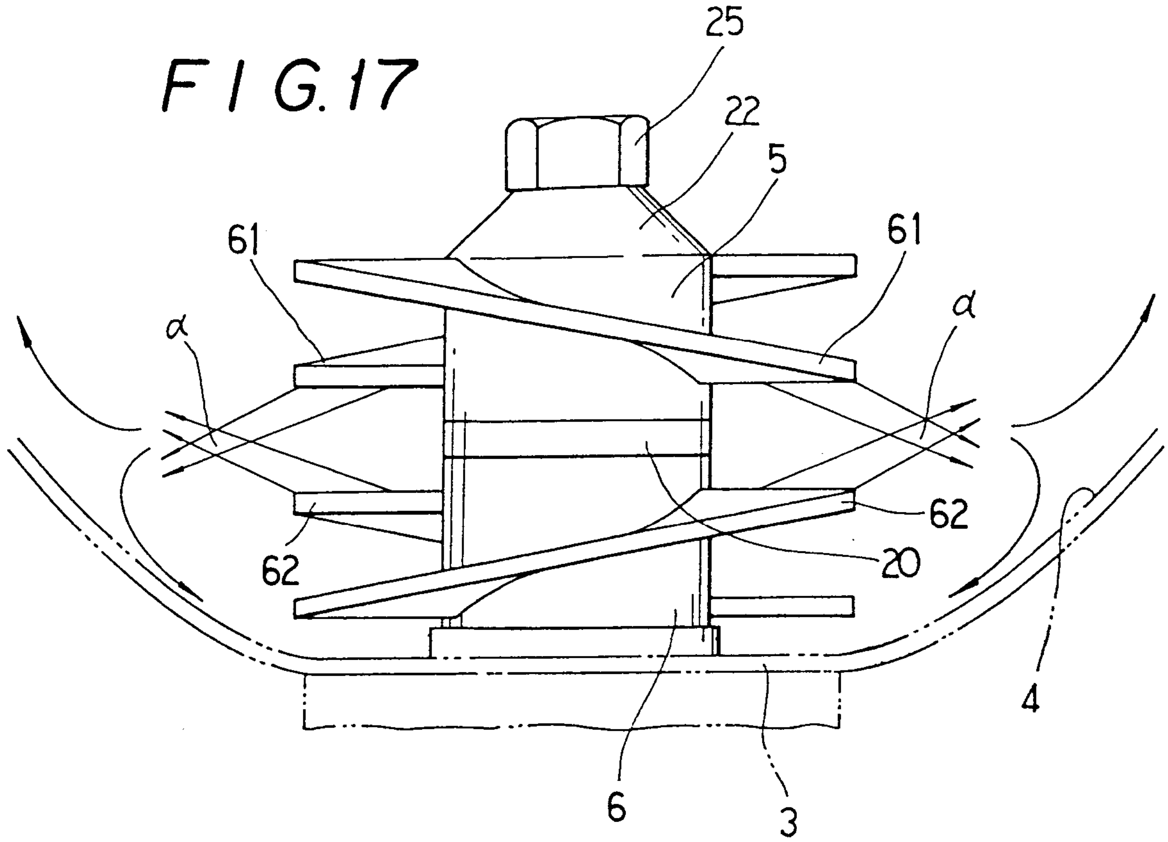
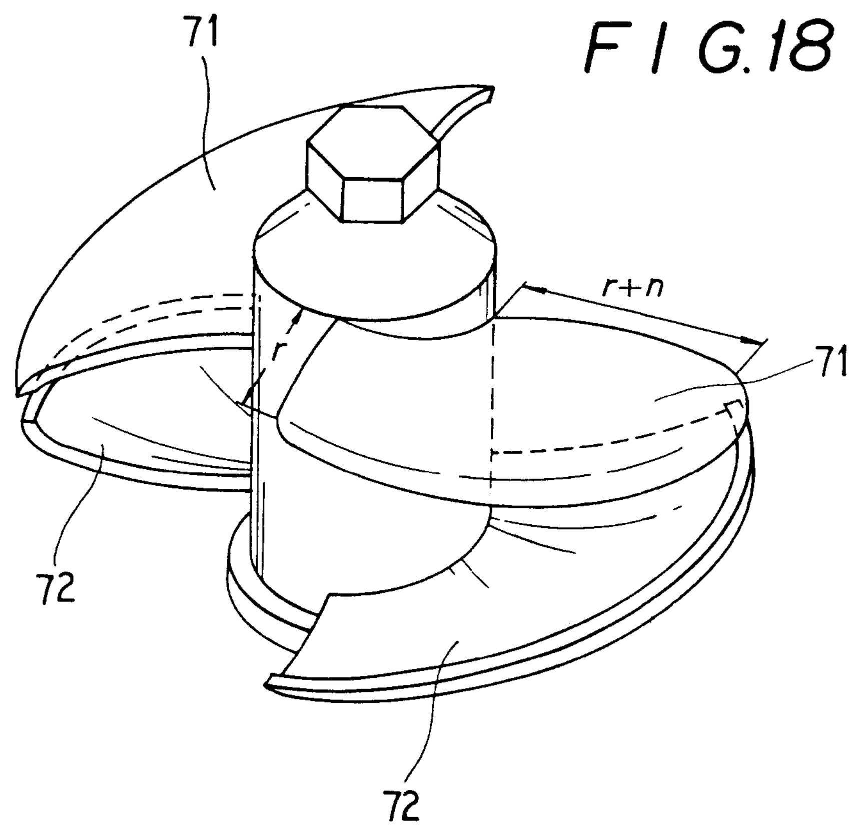


FIG.18



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EUROPEAN SEARCH REPORT

Application Number

EP 91 31 0662

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 305 576 (BAUKO BAUKOOPERATION) * figures 5,7 *	1-15	B01F15/00
A	FR-A-2 626 787 (WYSS)		
A	US-A-3 374 989 (TODTENHAUPT)		
A	FR-A-2 121 014 (ESSO RESEARCH)		
A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 185 (C-181)(1330) 13 August 1983 & JP-A-58 088 126 (NIHON ITA GLASS) * abstract *		
A	GB-A-1 187 632 (SCHAUBERGER)		

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B01F
A47J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	30 JANUARY 1992	PEETERS S.

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